AN ANALYSIS OF AIRFIELD THROUGHPUT AT ELMENDORF AIR FORCE BASE USING THE AIRFIELD SIMULATION TOOL

THESIS

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AFIT/GLM/ENS/02-07

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THESIS

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Andrew C. Jones

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Abstract

Elmendorf Air Force Base (AFB) is one of the two key en route airfields for the Pacific Theater. The condition of en route airfields has recently come to the attention of the DoD and the GAO. Delays at these airfields may cause personnel and equipment to arrive late in theater. Fuel systems at Elmendorf AFB are currently being improved, but the GAO questions whether these improvements will help the throughput.

As well as being an en route airfield, Elmendorf is also an important Interim Brigade Combat Team (IBCT) APOE for Fort Richardson. The IBCT is designed to operate in small-scale contingency operations in both complex and urban locations. The IBCT will be deployed within ninety-six hours between departure of first aircraft and arrival of last aircraft. The IBCT also requires fifty percent hazardous cargo loads, which reduces available parking for safety reasons.

This research uses the Airfield Simulation Tool (AST) to model both the en route and the IBCT scenarios. The focus of the modeling effort is to understand the limiting factors for both scenarios at Elmendorf AFB.

AN ANALYSIS OF AIRFIELD THROUGHPUT AT ELMENDORF AIR FORCE BASE USING THE AIRFIELD SIMULATION TOOL

I. Introduction

Statement of Problem

The United States Air Force (USAF) is requesting funding to update the fuel systems at strategic airlift en route airfields and also airfields to be used as origins for Interim Brigade Combat Team (IBCT) deployments. Planners at United States Transportation Command (USTRANSOM) are interested in the current fuel systems capability at these bases. In particular, my research will focus on Elmendorf Air Force Base's fuel system.

Elmendorf Air Force Base (AFB) is a strategic airlift en route airfield and also an airfield to be used as an Aerial Port of Embarkation (APOE) for the IBCT. Elmendorf AFB also supports tactical aircraft, so certain resources necessary for handling the airflow will become critical. When Elmendorf is used as an En Route, the parking and fuel are critical resources. When Elmendorf is used as an APOE, parking, cargo handling resources, maintenance resources, hazardous cargo pads, and fuel become critical resources. Fuel will be the primary concern at Elmendorf, since all aircraft require fuel.

In 1998, according to FY 1998 Military Construction Data, two above ground fuel storage tanks were constructed. In 1999, twelve refueling hydrants were replaced by a Type III pressurized fuel system. The remaining refueling hydrants are to be replaced by

a Type III pressurized fuel system. A June 22, 2000 General Accounting Office (GAO) Report discusses the lack of information on airfield deterioration and failure rates. Current data shows that without these improvements to the En Route Structure, military forces deploying through the En Route will arrive late.

Scope of Research

This research aims to determine what improvements are required of existing infrastructure at Elmendorf AFB with a focus on fuel systems and parking, modeling it as an En Route Airfield and an IBCT APOE. As a result of this, all cargo handling will not be modeled. To determine:

En Route Questions

- What are the limiting factors given a certain airflow rate for the Elmendorf AFB as an En Route Airfield?
- Will the expected improvements to the fuel systems be sufficient?
- What other improvements to Elmendorf's Infrastructure will be required?

IBCT Questions

- What are the limitations at Elmendorf for the IBCT?
- Will the addition of hazardous cargo parking spots improve the airflow for the IBCT?
- How many missions can be generated in seventy-two hours?
    - How many tons are moved?
    - How many diverts?
    - How much fuel was pumped?

Issues, Needs, and Limitations

- De-Icing is not modeled
- The equipment and fluid required to perform de-icing are not modeled
- The weather will be modeled using the “weather factor” option in the AST

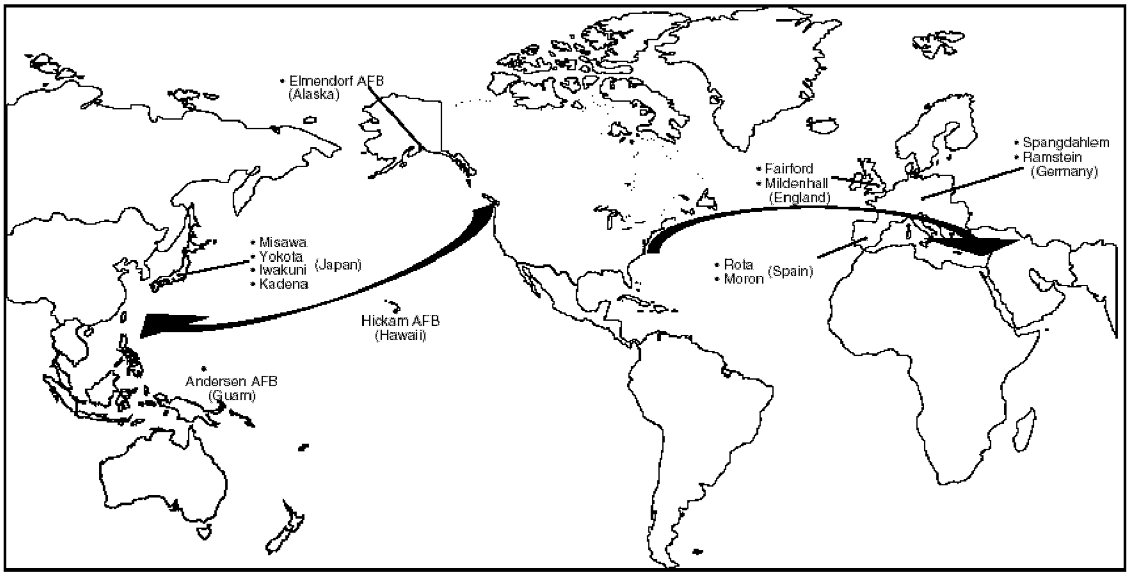
II. Literature Review

Introduction

Models have been developed to help Air Mobility Command (AMC) to optimize the use of their resources and determine airfield capacity. This section will explore the development of these models as it affects the use of the Airfield Simulation Tool (AST) for this particular study. The need for this study will also be discussed with past research of the En Route and IBCT APOE airfields. The current fuel system will be discussed and the planned improvements.

Research Importance

Current U.S. defense strategy requires that the Department of Defense be equipped "…to fight and win two nearly simultaneous major theater wars…" (United States General Accounting Office, 2001:4). "ERS [En Route System] airfields provide the primary 'throughput' services for aircraft as they move from U.S. bases through ERS airfields and on to their eventual destinations at bases located in or near war zones." (United States General Accounting Office, 2001:4) Elmendorf Air Force Base (AFB) is one of the two key ERS airfields for the Pacific Theater (See Figure 1 below). The condition of the En Route System recently has not only gained the attention of the Department of Defense (DoD), but also the attention of the GAO.

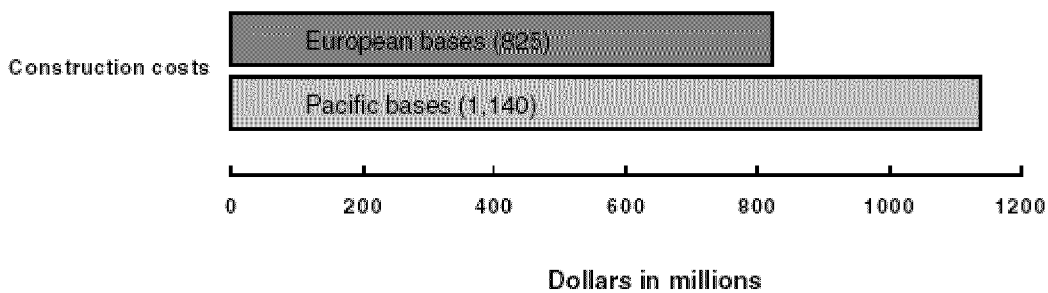


(United States General Accounting Office, 2001:Figure 1)

Figure 1. En Route Airfields

The GAO references the "...concern about aging and deteriorating facilities and equipment…(United States General Accounting Office, 2001:3)", as the reason for the recent focus on the ERS. As shown in Figure 2, the Pacific bases are the worst off for repairs and improvements. A January 2001 DoD estimate shows that in the event of the two nearly simultaneous major theater wars scenario that the ERS airfields are not capable of moving the aircraft through to the designated war zones on time (United States General Accounting Office, 2001:6). The delays may cause units to not receive needed reinforcements or supplies on time, increasing the risk of casualties (United States General Accounting Office, 2001:6). According to the Mobility Requirements Study 2005, the shortfalls at ERS airfields will be met by proposed construction projects. According to the GAO report, the Mobility Requirements Study 2005 assumes that ERS airfields would operate without failures (United States General Accounting Office, 2001:7). "Some study assumptions tend to underestimate the shortfall, while the

modeling approach used could overestimate it. The net effect of these factors on estimates of ERS capacity in 2005 is unclear." (United States General Accounting Office, 2001:6)

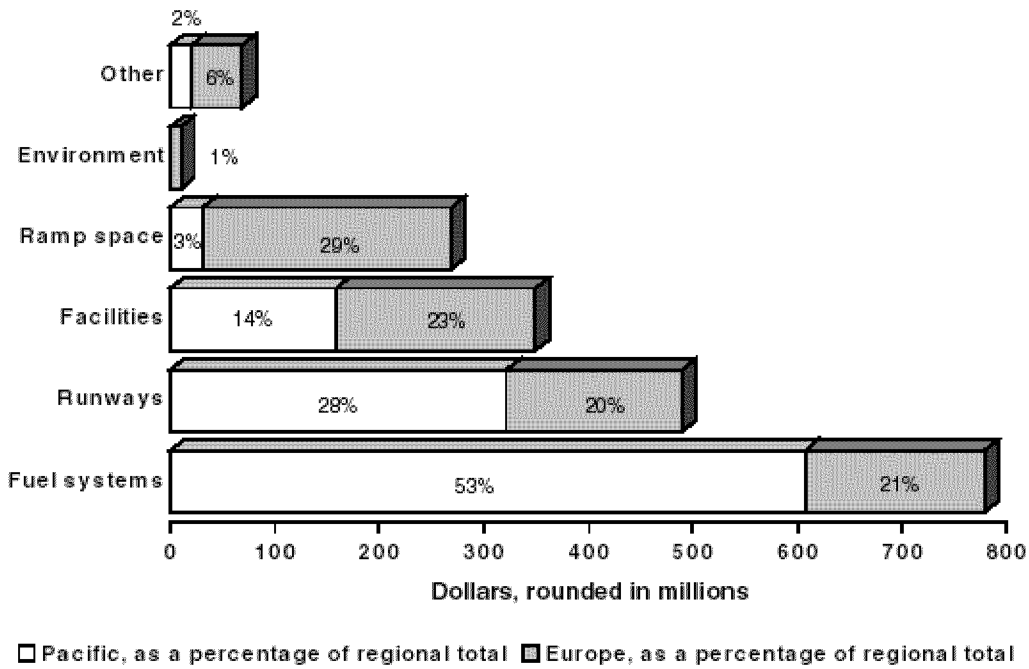


(United States General Accounting Office, 2001:Figure 6)

Figure 2. Theater Airfield Improvement and Repair Costs

There are doubts as to the benefits of the construction and whether or not the shortfalls will be met. The DoD lacks data on deterioration and failure rates of the facilities at ERS airfields (United States General Accounting Office, 2001:17). The lack of data on deterioration and failure rates is the focus of the current study with an emphasis on the fuel system. As identified in Figure 3, fuel systems in the Pacific Theater make up the largest percentage of the construction projects.

The GAO report recommends that the DoD "…develop an overall cost-benefit study to document the rationales for plans to repair and improve the ERS, and include information on ERS limitations and how they affect the Department's strategic mobility performance in DOD's performance plan and report." (United States General Accounting Office, 2001:22) The current study will provide the limitations of Elmendorf AFB and provide information necessary for USTRANSCOM to perform a cost-benefit analysis.

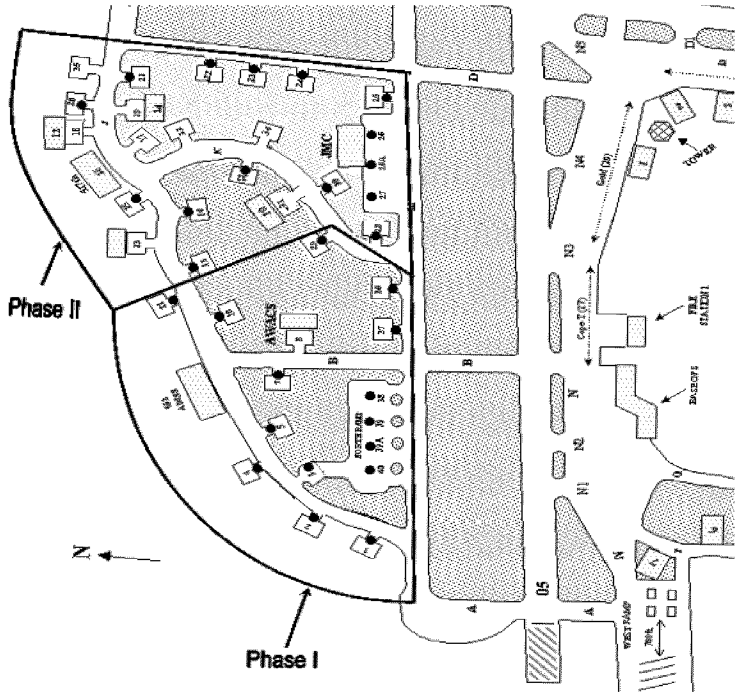


(United States General Accounting Office, 2001:Figure 3)

Figure 3. Project Costs

Fuels Information

The existing fuels infrastructure is over forty years old (DLA, 1999) at Elmendorf AFB. Lack of replacement parts and poor reliability limits the throughput capability of Elmendorf (DLA, 1999). The replacement of the Type I and II hydrant fueling systems on the North Ramp (See Figure 4) have been proposed for Phase I and II of the construction improvements (DLA, 1999).



(Commander's Action Group, 2000:Figure 4)

Figure 4. Project Map

Type III hydrant systems are a looping system allowing instant fuel flow. The Type I and II systems do not loop, so fuel pressure needs to build in the pipelines before fuel will flow. The Type I system is not able to defuel aircraft except by gravity. The Type II system is able to defuel, but slowly. The fuel system information has been provided by 3rd Wing Fuels Management Flight personnel.

En Route Studies

A previous study has been conducted using the AST (formerly known as the Base Resource and Capability Estimator [BRACE] model) at Elmendorf AFB to determine among alternatives, which fuel improvement project would best improve the aircraft throughput and to validate the use of the BRACE model (White et al, April 1997:3). The BRACE model was validated using system experts to determine if the results were

accurate (White et al, April 1997:2). This study originated because it was determined that Elmendorf AFB could only move sixteen percent of projected aircraft through without a delay as a result of the fuel system for a thirty day period (White et al, April 1997:2).

The study had five major assumptions, which directly affect the validity of the study (White et al, April 1997:4). The study first assumes that the base's resupply rate of fuel is able to support the planned flow (White et al, April 1997:5). The second assumption is that the system's performance is based on good weather (White et al, April 1997:5). The next assumption is that refueling trucks will be used for aircraft parked in spots without hydrants (White et al, April 1997:5). The fourth assumption is that there are fourteen KC-10s that Elmendorf is required to support for tanker bed down (White et al, April 1997:5). The KC-10s average 1.5 sorties per day and twenty-one total sorties per day (White et al, April 1997:5). The study next assumes that the existing fuel systems require long periods of time to repair and availability of the fuel systems was based on estimates provided by system experts (White et al, April 1997:5). The final assumption is that parking spots can only support certain aircraft, which is further explained in the study (White et al, April 1997:5). The results of this study suggest that if Phase I and II are completed, that a throughput of ninety one percent will be achieved (White et al, April 1997:12).

IBCT APOE Study

As well as being an ERS airfield, Elmendorf is also an important Interim Brigade Combat Team (IBCT) APOE for Fort Richardson. The IBCT is designed to operate in small-scale contingency operations in both complex and urban locations (Department of

the Army, December 2001:4). The IBCT will be deployed within ninety-six hours between departure of first aircraft and arrival of last aircraft (USTRANSCOM, April 2001:9). The IBCT deploys with no tracked vehicles (Godwin, May 2001:16), but the number of loads containing ammunition or explosives increases (USTRANSCOM, April 2001:9). The percentage of aircraft carrying hazardous cargo is estimated to be fifty percent. This is a significant increase, since the standard is ten to twenty percent.

Summary

The literature review demonstrated the importance of this study to USTRANSCOM and to the GAO. The effectiveness of the construction projects is important to the GAO, so that they may develop a cost benefit tradeoff. The literature also revealed the poor performance of the current fuel system and the need to upgrade to a Type III Hydrant System. The previous ERS study made some major assumptions and determined that Phase I and Phase II of the construction would yield a throughput of ninety one percent. The IBCT is a major change to the way the US Army deploys. As a result, this will affect airlift operations increasing the percentage of aircraft carrying hazardous cargo to fifty percent. The previous studies will serve as a guide for this research.

III. Methodology

Introduction

This chapter will describe the procedures used in this study. The two scenarios that require research, Elmendorf as an en route and an APOE, make it necessary to conduct two independent simulations. Both simulations are similar in approach, but the input data will be different because the en route does not require the movement of cargo, so the limiting factor at Elmendorf may change. The data collection method for the input data will be described and the methodology for each scenario is described.

Input Data Collection

The AST requires input data specific to the airfield that is being simulated. To collect the required data, several documents were used as well as a site survey to verify the accuracy of the information. A database for collecting the required data had previously been built for just this purpose. Three main groups were interviewed for the required input data and these groups were given the database to provide input to the simulation. Limitations of the model were identified.

The 3rd Wing Fuels Management Flight provided information regarding the fuels system. The "Elmendorf Base Support Plan: Chapter 19" was used to understand the fuels operations. The availability of the hydrant systems was a major topic of discussion. The fuels personnel and previous models assume one hundred percent availability of the hydrant fuel systems. As discussed in chapter II, the frequent failures of the Type I and Type II hydrant fuels systems as well as the better performance of the Type III system are the primary reasons for the construction projects to improve the hydrant fuels system at Elmendorf AFB. The site survey showed that Phase II of the construction has not been

completed. The personnel verified the accuracy of the information and completed the database.

The 732 Air Mobility Squadron (AMS) is responsible for the maintenance, cargo loading/offloading, passenger movement, and cargo handling/storage for all Air Mobility Command aircraft transiting through or originating from Elmendorf AFB. The document titled “Hardstand Parking: North and West Side” was used to understand the location and parking restrictions. The survey also allowed for the collection of information regarding the aerial port operations. The 732 AMS provided relevant information regarding operations and process times. Personnel from the 732 AMS identified the use of hardstands as opposed to parking ramps for parking heavy aircraft as a problem. The hardstands make parking more difficult because the aircraft have only one entrance and exit. Parking requires more time, personnel in some cases, and the need to be more accurate in parking so that other operations such as fueling and loading cargo can be accomplished without problems.

The Airfield Manager and his staff were the last group to be interviewed. The interview revealed potential problems for the future of the IBCT. According to the Airfield Manager, there have been complications in locating additional hazardous cargo parking spots required to handle the projected increase in aircraft carrying hazardous cargo loads. This problem has yet to be resolved, but is a work in progress.

En Route Simulation

The first simulation that will be conducted treats Elmendorf AFB as an en route. The model has been provided by USTRANSCOM to conduct this research. The simulation is the APOD Model using the AST. This tool models the operations involved in operating an Air Force Base used for airlift operations. The AST models maintenance, cargo handling, passenger processing, command and control, re-fueling, arrivals of aircraft based on input data, and provide output data showing delayed aircraft. Figure 5 (below) shows how the model schedules the service of each aircraft.

(USTRANCOM Slide Presentation)

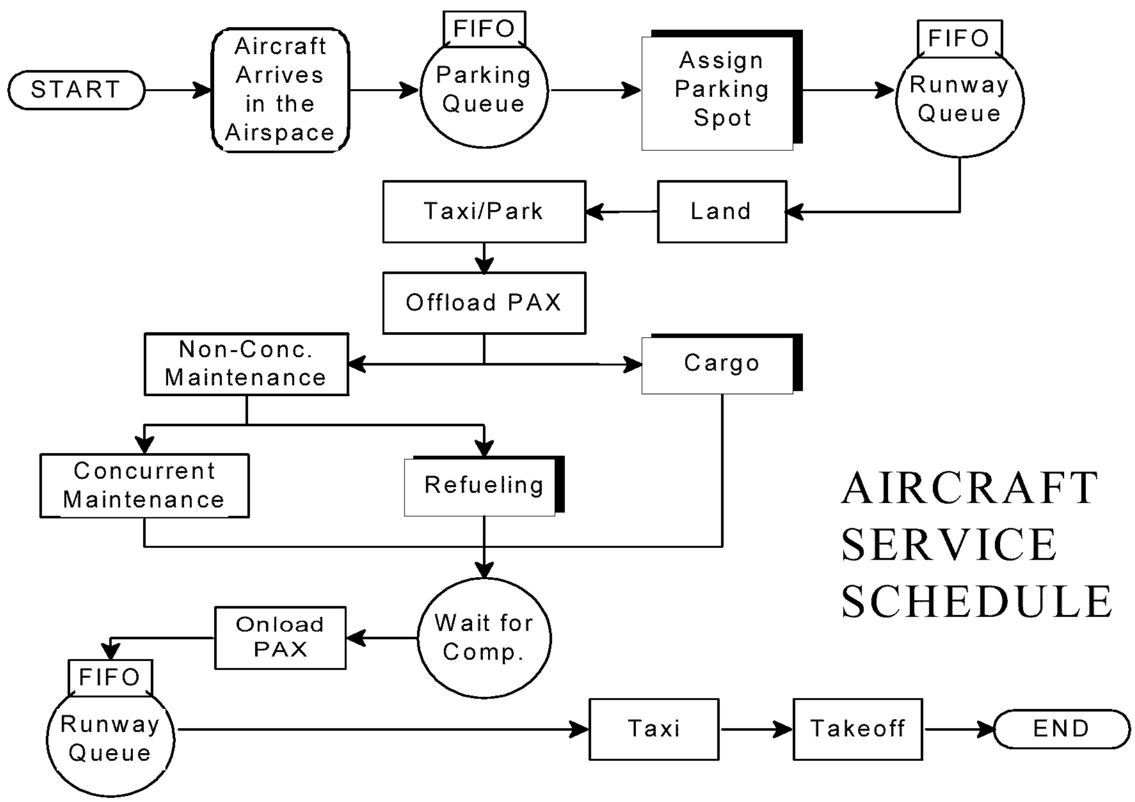


Figure 5. Aircraft Service Schedule

Only C-17s and C-5s will be used in the model, because the C-17 and the C-5 haul the majority of the cargo and personnel. The C-141s are gradually being phased out of service, so they are not considered in the simulation. Cargo operations will not be simulated since no cargo is moved in the En Route scenario. The AST will model the improved operation at Elmendorf AFB. The model simulates thirty days of operations. Elmendorf AFB has no operating restrictions, so the airfield is open twenty-four hours. The aircraft in the model have an exponential arrival rate with a varying mean depending upon the number of aircraft arriving per day. Aircraft in the landing queue will be diverted after two hours of waiting. Air Mobility Command has a standard fifteen-minute take off pad to forgive late departures, which will also be included in the model. USTRANSCOM assumes that no hazardous cargo will be moved in the En Route scenario. Therefore, the hazardous cargo parking is not an issue in this scenario and will not limit the available parking as it would if it were included.

The Maintenance Details required for the model require the break down rate by aircraft type and the time to repair. The break rate by aircraft has been provided as well as the repair time (See Appendix B). The data needs to be manipulated by multiplying the break rate by each repair time to obtain the needed maintenance data, which includes break down rate and time to repair.

The parking ramps have been set up to model the twenty-five parking spots available for the en route aircraft and the bed down KC-10s. (See table #1 for detailed aircraft parking information) The spots listed without hydrant outlets in Phase I of construction receive them in the improvements in Phase II.

Table 1. En Route Aircraft Parking Information

Ramp #	Type of Parking Spots with/without Hydrants	A/C Permissions	A/C Taxi Time	Nearest Fill Stand	MH2/HSV Travel Time	MHE Cross Active Runway (Yes/No)
1	4 WB/4	All	10 min	1	10/5	Yes
2	4 WB/4	All	10 min	2	20/20	No
3	1 WB/1	All	12 min	2	20/20	No
4	3 WB/3	C-17, KC-10	12 min	2	20/20	No
5	9 WB/1	C-17, KC-10	12 min	3	20/20	No
6	3 WB/2	C-17, KC-10	12 min	3	20/20	No
7	1 WB/1	C-17, KC-10	12 min	3	20/20	No

The fuel resources are also based on interviews with fuels personnel at Elmendorf AFB. Fuel equipment breakdowns will be simulated based on the provided failure data.

Table 2. Fuel Resources

Fuel Equipment #	MTBF (Hrs)	MeanRT (Hrs)	MinRT (Hrs)	MidRT (Hrs)	MaxRT (Hrs)
Large Trucks-20	36	10.75	.25	8	24
Small Trucks-0	36	10.75	.25	8	24
MH2-9	72	23.3333	1	17.999	48
HSV-3	72	23.3333	1	17.999	48

Equipment	Setup Time	Fuel Flow
MH2	3 min	500 GPM
HSV	3 min	960 GPM

As indicated earlier, the hydrant systems are where the current scenario varies from the improved. The improved airfield will have three bulk fuel tanks and 3 fill stands with the same characteristics identified in Table 3 and 4 respectively. The

improved systems have a refill level of twenty thousand gallons. The hydrant system is represented in Table 5.

Table 3. Bulk Fuel Information

						Pipelines	Headers
					Max Tanks Service Simultaneously	1	0
					Max Receiving Rate (gph)	108000	50000
					Max Receiving Hours Per Day	20.000	20.000
Tank ID	**Tank Number**	**Max Fuel Supply Rate (gph)**	**Initial Level (Gallons)**	**Usable Capacity (Gallons)**	**Refill Level**	**Receiving Rate (gph)**	**Recovery Time (min)**
1	1	108000	3000000	3320539	20000	108000	0
2	2	108000	3000000	3320539	20000	108000	0
3	3	108000	3000000	3320539	20000	108000	0

Table 4. Fill Stand Information

Fill Stand Location	Fill Stands	Number of Tanks	Total Capacity (Gallons)	Receiving Rate (gph)
1	2	0	600000	124200
2	4	0	600000	124200
3	2	0	600000	124200
			Refill Level	20000

Table 5. Hydrant Information

Hydrant System	Hose Cart Type	# of Tanks	# of Laterals	Max Active Outlets	Hydrant pump Rate (gph)	Avail. (%)	Total Capacity (Gallons)	Receiving Rate (gph)
1	HSV	2	1	4	600	100	756000	72000
2	HSV	2	1	4	600	100	756000	72000
3	HSV	2	1	4	600	100	756000	72000

The aircraft preferences were set in accordance to AFPAM 10-1403 and the scenario that is being modeled (See Table 6). The fuel required is based on a scenario requiring the cargo aircraft to fly to Yokota AB, Japan. Aircraft are usually only given the required fuel to make a particular destination with a factor of safety. The fuel required for the cargo aircraft are based on aircraft arriving empty except for the factor of safety. The KC-10 requirements are based on the fuel capacity of the aircraft.

Table 6. En Route Aircraft Preferences

Aircraft Type	En Route Standard Ground Time (Hours)	Reason	Fuel Required (Gallons)
C-5	3.25	En Route	29104.48
C-17	2.25	En Route	22388.06
KC-10	3.25	En Route	50746.27

The first simulation will be run varying the number of missions planned per day, the mix of aircraft used, and the modeling of aircraft breaks using the scenario with improvements included. Three aircraft mixes will be considered: All C-5s/0 C-17s, 50% C-5s/50% C-17s, and All C-17s. A comparison of planned versus actual missions per day departing from Elmendorf will follow as shown in Tables 7 and 8. This data will give an initial look at the capabilities of Elmendorf with regard to number of missions per day.

Table 7. Sample Output Table

Determine Actual Missions per Day (No A/C Breaks)					
	Missions Planned per Day				
C-5/C-17 Mix	**20**	**40**	**60**	**80**	**100**
100/0					
50/50					
0/100					

Table 8. Sample Output Table

Determine Actual Missions per Day (A/C Breaks)					
	Missions Planned per Day				
C-5/C-17 Mix	20	40	60	80	100
100/0					
50/50					
0/100					

From this same data, the number of missions planned versus the average number of missions delayed per day will be determined and graphed. From the average number of actual missions per day, the average short tons per day will be calculated using payload-planning factors. The average short tons for each aircraft mix will be compared to the number of missions per day planned. Fuel consumption per day will be compared to the number of missions planned using the three different aircraft mixes.

Using the initial simulations at different levels, the analysis will focus on the most realistic aircraft mix and the break point where the number of missions planned is not attainable. An additional simulation will be conducted at the level where the planned missions are initially not attainable and the level prior to this. These additional runs will be run for one thousand days. This allows for a one hundred day warm up period and thirty independent runs of thirty days to develop a confidence interval at both levels. Fuel system availability is assumed to be one hundred percent. To ensure that this assumption is valid, using the determined optimal mix of aircraft, the simulation will be run for one hundred and ninety percent and the output will be compared. Last, the average delay time will be determined from the data to allow for the comparison to the number of missions planned and to the aircraft mix.

En Route Model Assumptions

- 14 KC-10s are bed down at Elmendorf flying 21 missions per day
- All A/C required are available
- No hazardous cargo moved per USTRANSCOM
- Fuel tanks are full
- Supplied data is accurate
- The use of fuel trucks at hydrant spots will not be simulated

IBCT APOE Simulation

The second simulation will be conducted similarly to the first except Elmendorf AFB will be modeled as an APOE for the IBCT. The focus of this simulation is on the hazardous cargo parking and its effects on the rapid deployment of the IBCT. The input data does not change except the KC-10s are not included and the parking spots are restricted based on "Hardstand Parking: North and West Side". There are a total of seventeen spots and three of them are Hazardous Cargo Spots.

Table 9. IBCT Parking Information

Ramp #	Type of Parking Spots with/without Hydrants	A/C Permissions	A/C Taxi Time	Nearest Fill Stand	MH2/HSV Travel Time	MHE Cross Active Runway (Yes/No)
1	4 WB/4	All	10 min	1	10/5	Yes
2	2 WB/2	All	10 min	2	20/20	No
3	8 WB/8	C-17	12 min	3	20/20	No
4	2 WB/2	C-17	12 min	3	20/20	No
5	1 WB/0	All	12 min	3	20/20	No

The percentage of the aircraft carrying hazardous cargo increases to fifty percent. USTRANSCOM has modeled a sample deployment of the IBCT to Sri Lanka requiring

the IBCT to deploy within seventy-two hours from Elmendorf AFB allowing the last aircraft to depart Elmendorf AFB to arrive in Sri Lanka within the ninety-six hour time requirement. This will require two hundred and twenty four missions requiring 136 C-17s and 88 C-5s.

The number of hazardous cargo spots will be varied between three and five to determine if additional hazardous cargo spots will allow for the IBCT to deploy within the seventy-two hour window that has been given. Using the assumed aircraft per day, the amount of cargo moved, the fuel pumped, and the number of aircraft diverted will be determined. The amount of hazardous cargo will be modeled at fifty percent and twenty-five percent. If the IBCT is unable to deploy in the seventy-two hour window, then the number of days required to deploy will be reported.

IBCT Model Assumptions

- All A/C required are available
- Baseline of 30 C-5s per day and 46 C-17s per day will be used with 50% hazardous cargo
- Cycling of aircraft happens automatically and is not modeled
- The cargo movement from Fort Richardson to Elmendorf will not be modeled and cargo operations at Elmendorf will not be modeled
- Supplied data is accurate
- The use of fuel trucks at hydrant spots will not be simulated

Summary

Chapter III identified the input data that is used to run the model and the method of collection. The two scenarios were described and how the model simulates the two

scenarios differently. The simulation allows for the identification of the limiting factors for each scenario. The assumptions for each scenario are included.

IV. Analysis of Results

Introduction

The simulation of Elmendorf as an En Route and as an IBCT APOE resulted in a significant amount of information. From the information, data required to answer the research questions has been extracted. The extraction method will be presented along with the resulting data. The analysis of the results will answer the research questions previously presented.

Data Extraction

The simulations resulted in a great deal of information. The data was extracted using a macro developed in Microsoft Visual Basic within Microsoft Excel. The macro extracted the number of each type of aircraft departing per day, the amount of fuel pumped per day, and the number of aircraft diverts per day for each scenario.

En Route Data Presentation

The simulation was run for each mix of aircraft with the different arrival rates to determine the ideal mix and arrival rate to perform the rest of the analysis. The resulting data is shown below in Tables 10 and 11. All output tables are included, but the focus will be on the simulations without aircraft breaks because of the variability this introduces. It is generally understood that aircraft breaks will delay throughput, but the focus of this study is on parking and fueling systems. The reported data does not include the any information regarding the KC-10s, unless otherwise noted.

Table 10. En Route Output (A/C Breaks)

Determine Actual Missions per Day (A/C Breaks)					
	Missions Planned per Day				
C-5/C-17 Mix (%)	20	40	60	80	100
100/0	20.63	40.6	54.03	63.13	68.03
50/50	20.167	39.83	60.67	70.57	76.63
0/100	20.4	34.03	32.93	40.1	36.73

Table 11. En Route Output (No A/C Breaks)

Determine Actual Missions per Day (No A/C Breaks)					
	Missions Planned per Day				
C-5/C-17 Mix (%)	20	40	60	80	100
100/0	20.7	41.4	59.57	62.1	68.37
50/50	20.97	40.9	59.47	73.03	75.33
0/100	20.73	40.83	52.23	53.8	55.53

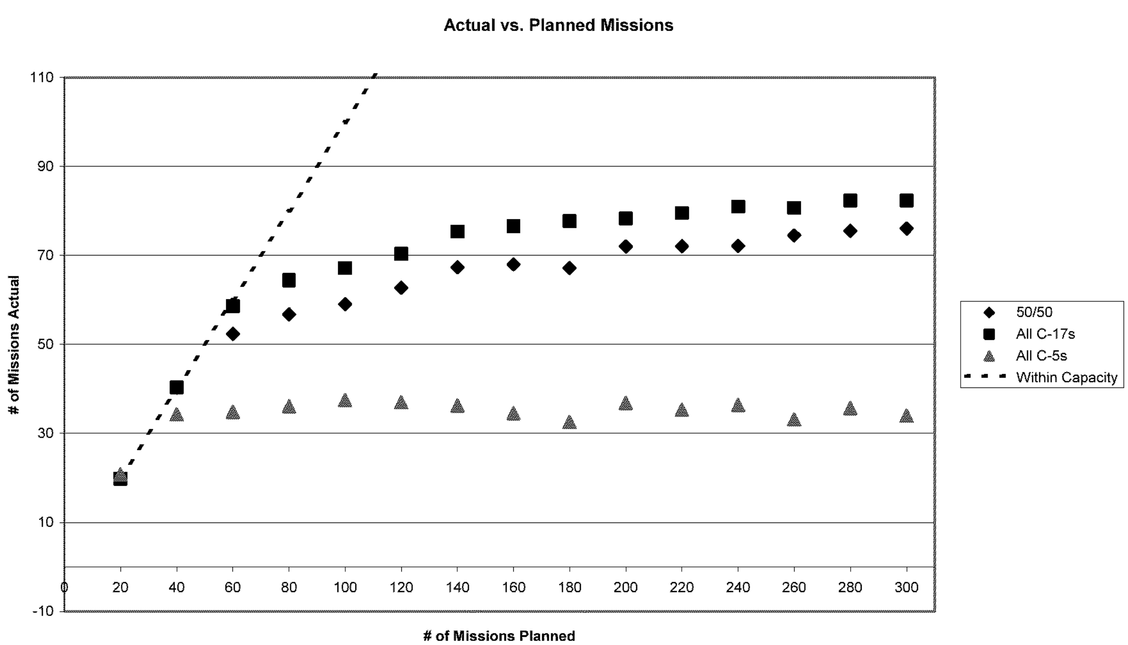


Figure 6. Actual vs. Planned Missions (A/C Breaks)

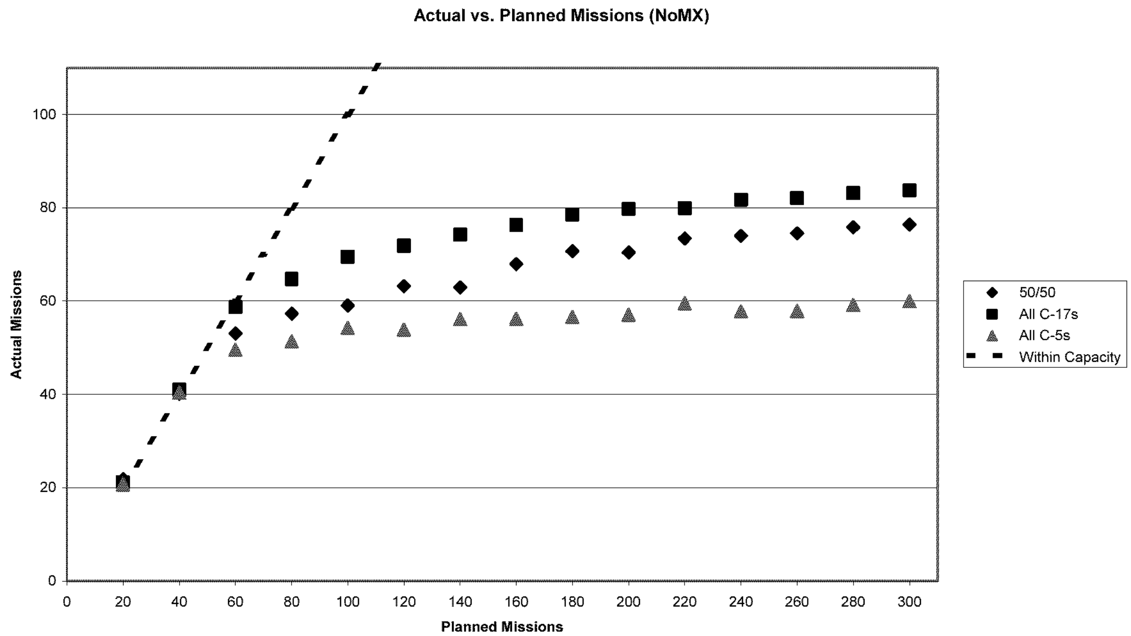


Figure 7. Actual vs. Planned Missions (No A/C Breaks)

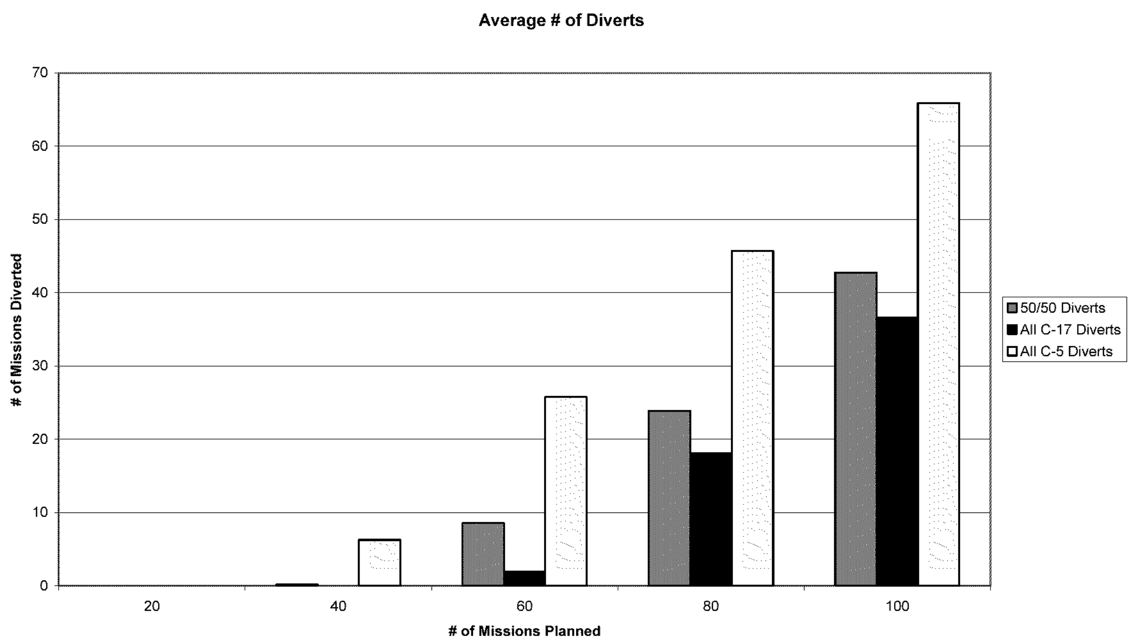


Figure 8. Diverts vs. Planned Missions (A/C Breaks)

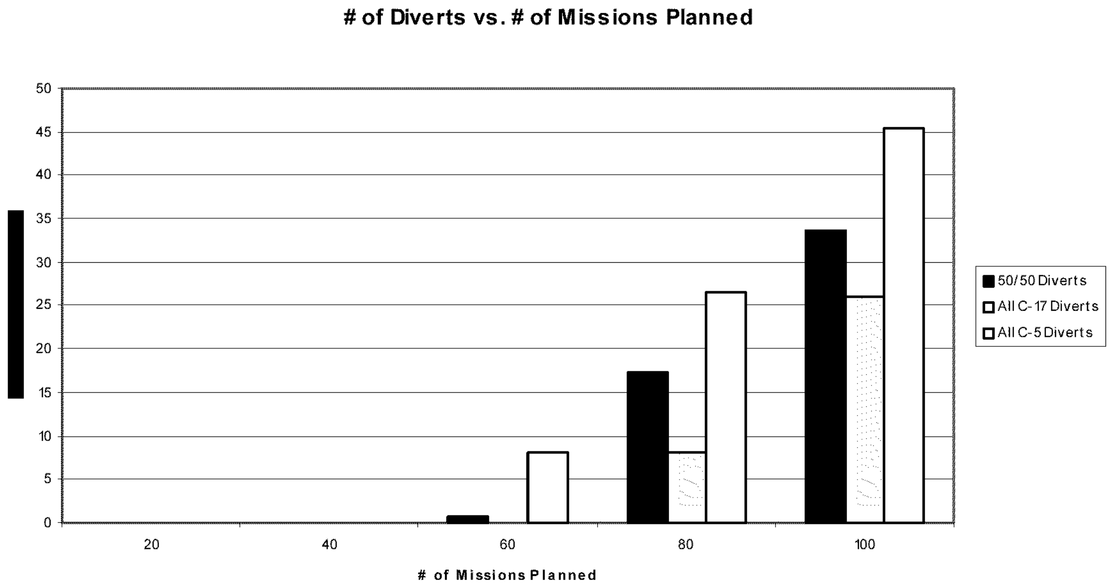


Figure 9. Diverts vs. Planned Missions (No A/C Breaks)

En Route Analysis

The simulations were first run with aircraft breaks on, so that realistic throughput can be reported. The aircraft breaks were then turned off, so that the aircraft breaks would not be a factor in the determination of the limiting factors at Elmendorf AFB. As Figure 6 demonstrates, the number of missions that are actually generated starts to diminish at sixty arrivals per day meaning that Elmendorf AFB can handle sixty missions per day maximum of the fifty-fifty and the all C-17 mixes. Analysis will begin to determine why the number of actual missions generated diminishes after sixty. This analysis was conducted using the fifty-fifty mix only since the all C-17 mix would require more C-17s than the USAF currently have in inventory. The simulation of aircraft breaks was turned off, so that this would not be a factor in the determination of the limiting factor. The queues for parking, refueling, and hydrants were all full in the

fifty-fifty, eighty missions per day scenario. To determine the limiting factor, the analysis focused on these three sections.

The airfield capacity starts decreasing at sixty missions per day (see Figures 6 and 7). This is a result of the limited number of C-5 parking spots available. Eventually, the airfield is completely saturated demonstrated by the decrease and eventual flattening out of the number of actual missions generated per day. Figures 6 and 7 show where the saturation occurs. As a result of the decrease in airfield throughput, the average diverts increases (see Figures 8 and 9).

To determine the limiting factor, first, the number of refueling resources was increased (14 HSVs, 11 MH2s) to rule out the fuel system as the limiting factor. The result is no increase in the number of actual missions generated. Next, the number of C-5 parking spots was increased on the West Ramp and the refueling resources were returned to normal. There was a minor increase in the number of actual missions generated, so the number of C-5 parking spots on West Ramp was increased further to twelve. This resulted in a further minor increase in the average number of missions generated. The increase of the West Ramp parking spots to twenty and the increase in the refueling resources resulted in little change. Refueling trucks were not modeled, so the actual number of missions generated should be more in reality. No significant change in the number of missions generated was seen by increasing parking or refueling resources.

The refueling resources and parking are not the limiting factor. A simplistic approach allows for the determination of the limiting factor. Taking into account the existing fuel in the three bulk tanks and the fuel required to refuel the eighty missions per day, a simple analysis is performed to determine if incoming fuel to the bulk tanks limits

the throughput. The receiving capability per day is 2,160,000 gallons per day (Department of the Air Force, 6 November 2001:4). The hydrants and bulk fuel tanks are full containing 11,815,366 gallons of fuel. The eighty mission plus the twenty-one KC-10s per day require 3,125,373 gallons of fuel based on the previous parameters discussed in Chapter III.

Table 12. Fuel Receiving (Deterministic Approach)

Day	Receiving	Dispensed	Existing Hydrant Tanks	Existing Bulk Tank	Total Fuel Available (Gallons)
0	0	0	2,268,000	9,547,366	11,815,366.00
1	2,160,000	3,125,373.27			10,849,992.70
2	2,160,000	3,125,373.27			9,884,619.46
3	2,160,000	3,125,373.27			8,919,246.19
4	2,160,000	3,125,373.27			7,953,872.92
5	2,160,000	3,125,373.27			6,988,499.65
6	2,160,000	3,125,373.27			6,023,126.38
7	2,160,000	3,125,373.27			5,057,753.11
8	2,160,000	3,125,373.27			4,092,379.84
9	2,160,000	3,125,373.27			3,127,006.57
10	2,160,000	3,125,373.27			2,161,633.30
11	2,160,000	3,125,373.27			1,196,260.03
12	2,160,000	3,125,373.27			2,308,86.76
13	2,160,000	3,125,373.27			-734,486.51

The deterministic approach in Table 12 shows that Elmendorf AFB will run out of fuel dispensing the required amount of fuel for eighty missions a day by day thirteen. This is an approximation assuming that all of these parameters remain constant. Table 12 shows that Elmendorf is restricted by the amount of fuel it receives a day.

Table 13. Ground Times (Deterministic Approach)

Aircraft Type	Ground Time	# Per day	Parking Spots	# Per day
C-5	3.25	7	8	56
C-17	2.25	10	10	100
KC-10	3.25	7	5	35

Using a similar approach, the parking situation can be analyzed. The ground times required for each aircraft are depicted in Table 13. Based on the ground time for each aircraft, the number of aircraft per day is calculated by dividing twenty-four hours by the ground times. Assuming that the parking spots are dedicated for each type of aircraft allows for the determination of each type of aircraft that can be parked at Elmendorf AFB. Clearly, parking is not the limiting factor.

Using the same product mix, the model was run at sixty missions per day and eighty missions per day for one thousand days. The one thousand day simulations utilized all of the computer memory. The model was rerun for six hundred and thirty days. Thirty days are the warm up period. Because steady state is reached, the next six hundred days provides a sample size of twenty independent periods of thirty days. This varies the seeds of the aircraft and the airfield. Analysis of the output allows for the development of a confidence interval for both levels. We are unable to invoke the central limit theorem allowing us to assume normality because the sample size is not large enough. The output from both the sixty and eighty missions per day are assumed to be normal based on their normal quantile plots and associated histograms with fitted normal distributions in Figures 10 and 11, respectively. With the normality of these samples established, it is now possible to develop a confidence interval for each sample.

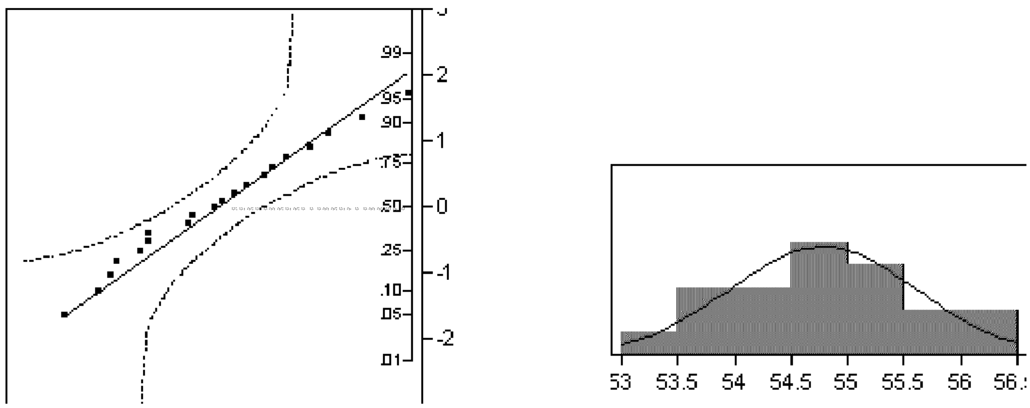


Figure 10. Normal Quantile Plot and Histogram for Sixty Missions Per Day

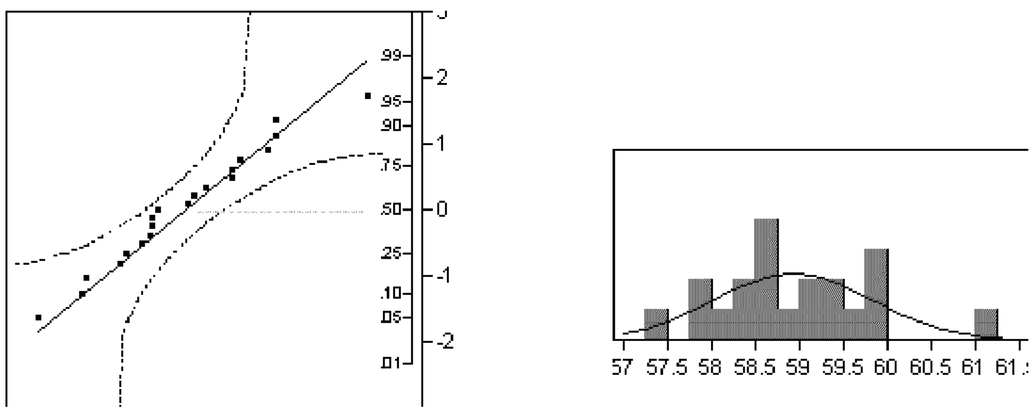


Figure 11. Normal Quantile Plot and Histogram for Eighty Missions Per Day

The ninety five percent confidence interval is shown for both the sixty and eighty missions per day shown in Figures 12 and 13.

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	54.78833	54.40219	55.17448	0.950
Std Dev	0.825066	0.627455	1.205068	

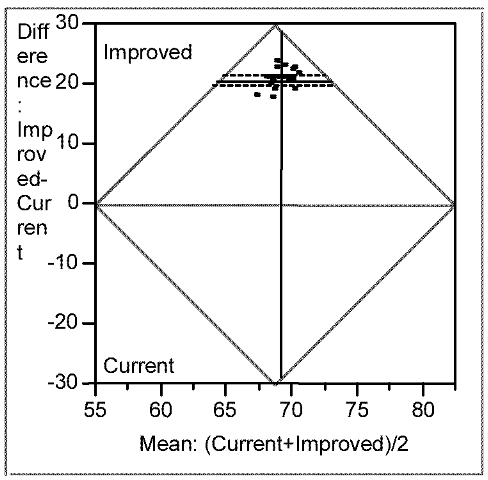
Figure 12. Ninety Five Percent Confidence Interval For Sixty Missions Per Day

Confidence Intervals

Parameter	Estimate	Lower CI	Upper CI	1-Alpha
Mean	58.925	58.50247	59.34753	0.950
Std Dev	0.902814	0.686581	1.318625	

Figure 13. Ninety Five Percent Confidence Interval For Eighty Missions Per Day

The bulk tank receiving capability was improved to the required to process eighty of the fifty-fifty mix (see Dispensed value in Table 12). The model was then rerun using the same process above to develop the confidence intervals. The resulting data was based on eighty missions per day using the product mix. This allowed for the determination if the change in average missions per day was significant when improving the bulk fuel tank receiving. The two runs are considered dependent because the iterations share the same starting seed. Using a paired t-test, the difference was determined to be significant (see Figure 14).



Improved	79.5783	t-Ratio	57.83838
Current	58.925	DF	19
Mean Difference	20.6533	Prob > |t|	<.0001
Std Error	0.35709	Prob > t	<.0001
Upper95%	21.4007	Prob < t	1.0000
Lower95%	19.9059		
N	20		
Correlation	0.07006		

Figure 14. Paired t-test Results

The average short tons per day, the average number of delays per day, and the average fuel consumption per day were all outputs of the model and are depicted in the following figures. The short tons were based on an average load per aircraft. The average delays per day were determined extracted from the output of the model. Finally,

the average fuel dispensed per day was extracted from the model output and includes the KC-10 fuel consumption. No analysis was performed using the following data, but is important information for USTRANSCOM.

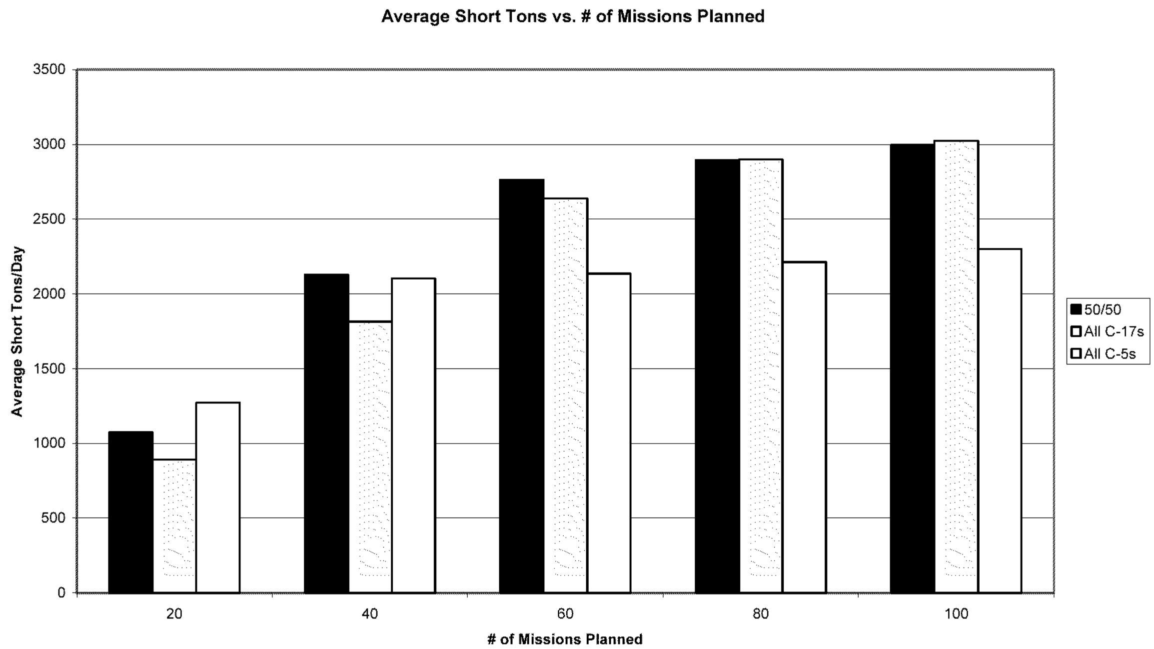


Figure 15. Average Short Tons Per Day (A/C Breaks)

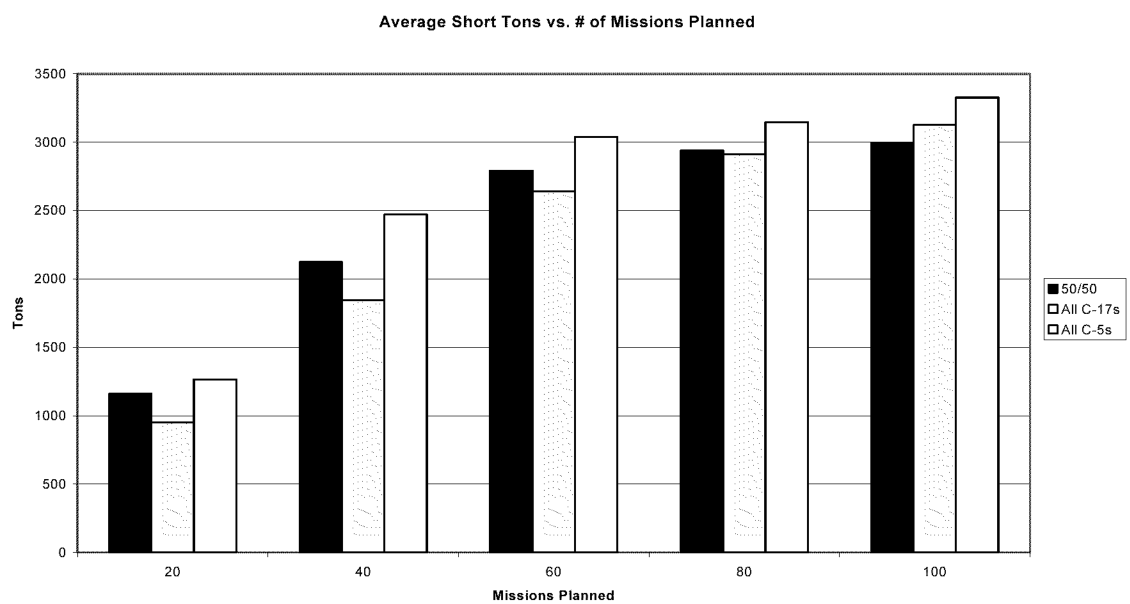


Figure 16. Average Short Tons Per Day (No A/C Breaks)

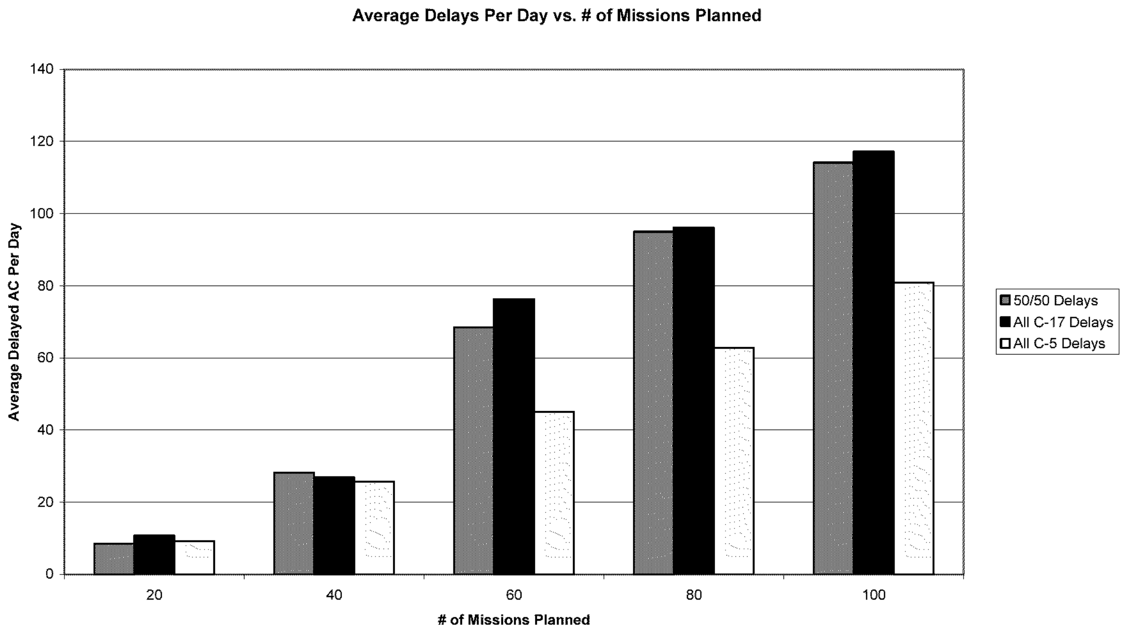


Figure 17. Average Delays Per Day (A/C Breaks)

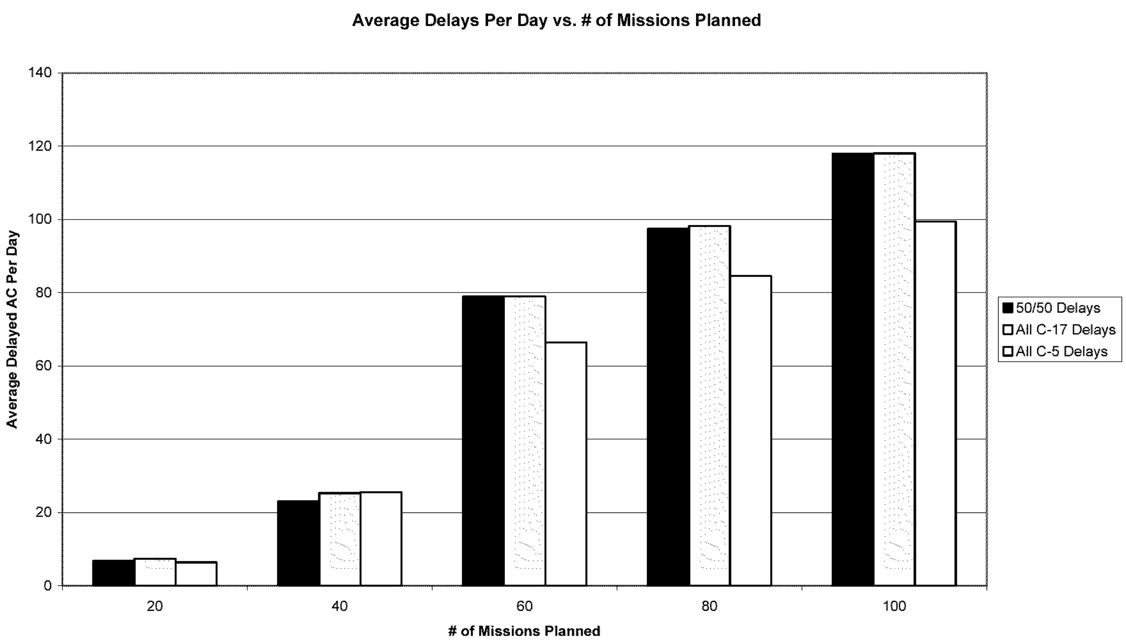


Figure 18. Average Delays Per Day (No A/C Breaks)

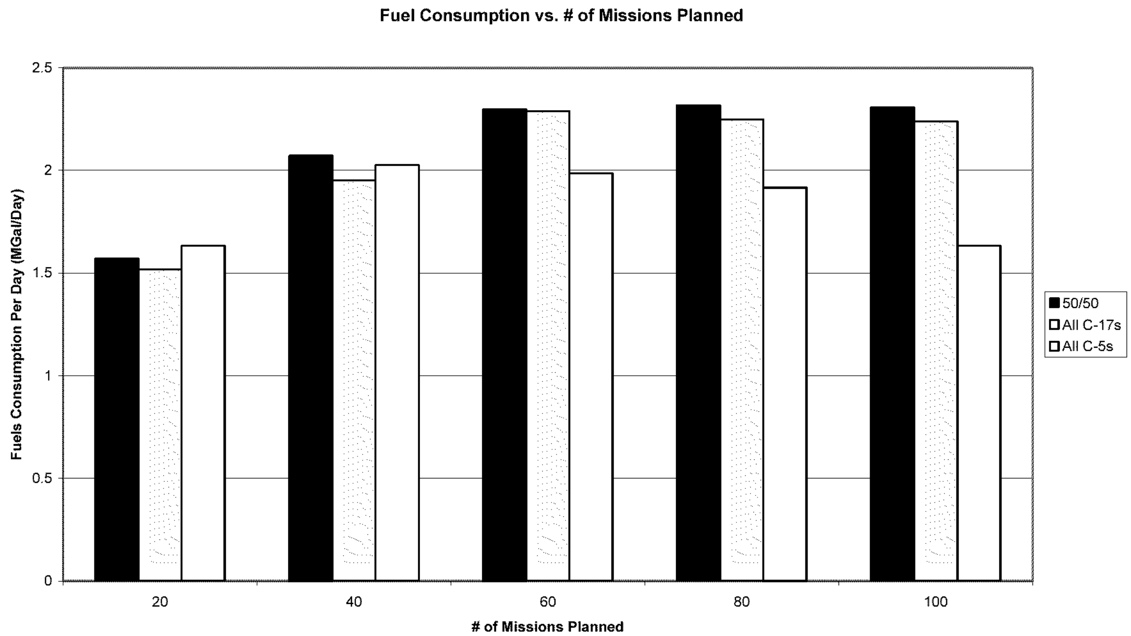


Figure 19. Fuel Consumption Per Day (A/C Breaks)

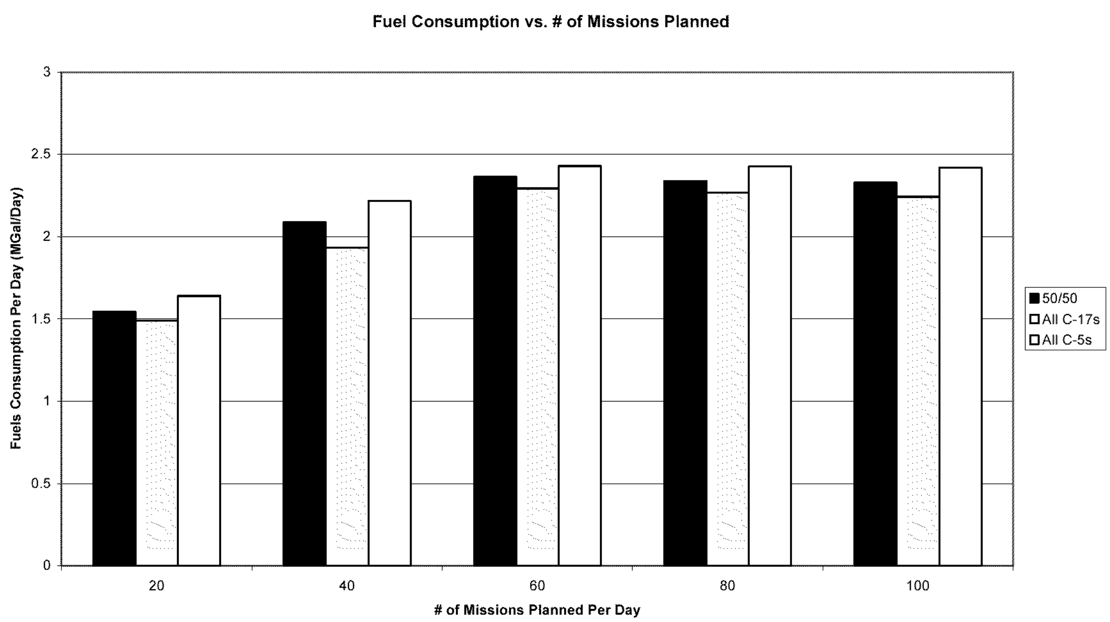


Figure 20. Fuel Consumption Per Day (No A/C Breaks)

Answers to En Route Research Questions

- What are the limiting factors given a certain airflow rate for the Elmendorf AFB as an En Route Airfield? The limiting factor at Elmendorf AFB is the amount of fuel that can be received per day.

- Will the expected improvements to the fuel systems be sufficient?

- The expected improvements to the fuel systems will be sufficient to generate sixty missions per day.

- What other improvements to Elmendorf's Infrastructure will be required? The West Ramp has space available for four new wide body parking spots, but has not been approved for use. The increase in available C-5 parking will improve throughput at Elmendorf and decrease the number of C-5 diverts.

IBCT Data Presentation

Table 14. No MX 50% Hazardous Cargo w/ Current Configuration

Day	# C-17s Arriving	# Of C-5s Arriving	Fuel Pumped	# Of C-17s Departing	# Of C-5s Departing	# Of A/C Diverted
1	46	32	1961194	42	25	9
2	33	17	1233582	33	21	20
3	39	15	1309702	43	18	18
			4,504,478	**118**	**64**	**47**

Table 15. No MX 25% Hazardous Cargo w/ Current Configuration

Day	# Of C-17s Arriving	# Of C-5s Arriving	Fuel Pumped	# Of C-17s Departing	# Of C-5s Departing	# Of A/C Diverted
1	56	31	2155970	51	26	1
2	39	30	1746269	40	30	1
3	43	21	1573881	47	26	5
			5,476,120	**138**	**82**	**7**

Table 16. No MX 50% Hazardous Cargo w/ 2 Additional Hazardous Spots

Day	# Of C-17s Arriving	# Of C-5s Arriving	Fuel Pumped	# Of C-17s Departing	# Of C-5s Departing	# Of A/C Diverted
1	49	31	1999254	43	25	8
2	41	23	1587314	42	27	7
3	43	24	1661194	48	26	2
			5,247,761	**133**	**78**	**17**

IBCT Data Analysis

Tables 13 and 14 represent simulations of the IBCT deployment with aircraft breaks turned off with fifty and twenty-five percent hazardous cargo, respectively. The required throughput is 136 C-17s and 88 C-5s in three days. In Table 14, it shows that at a reduced percentage of hazardous cargo, Elmendorf AFB is just short of meeting the required throughput for the IBCT. C-5 ground time for on loading cargo is 4.25 hours while a C-17 is only 2.25 hours. The reduction in hazardous cargo improves the throughput. The hazardous cargo parking is the limiting factor for deployment of the IBCT. As a result, an additional simulation with increased hazardous parking to five was conducted without eliminating or modifying any existing parking spots. Table 15 shows that the aircraft throughput increases for fifty percent hazardous cargo, when there are two additional hazardous parking spots.

Answers to IBCT Research Questions

- What are the limitations at Elmendorf for the IBCT?

  The limitations of Elmendorf as an IBCT are the available hazardous cargo parking spots. Currently, there are three hazardous cargo parking spots. Charlie Loop does not have a hydrant, but all aircraft can park there. Spot 20 has a hydrant, but C-5s cannot park there. Spot 42 is capable of parking all aircraft types and has a hydrant.

- Will the addition of hazardous cargo parking spots improve the airflow for the IBCT?

  Yes, but the increase in hazardous cargo parking while removing non-hazardous parking does not improve throughput.

- How many missions can be generated in seventy-two hours?

  118 C-17s and 64 C-5s can be processed

  - How many tons are moved?

    3,923.2 tons are moved by C-5s and 2,880 tons are moved by C-17s with a total of 6,813.2 tons

- How many diverts?

  47 Aircraft diverts

- How much fuel was pumped?

  5,247,761 gallons of fuel pumped

Summary and Conclusions

The simulation of Elmendorf AFB as an en route and as an IBCT APOE provided data that answered the research questions. Further analysis allows for a better understanding of these two different scenarios at Elmendorf AFB. As an En Route, the fifty-fifty aircraft mix is the focus of the analysis. With the en route scenario, Elmendorf AFB is limited by the amount of fuel that can be received. As an IBCT APOE, Elmendorf AFB is limited by the number of hazardous cargo parking spots.

V. Conclusion and Recommendations

Summary of Findings

The en route scenario is limited by the amount of fuel that can be received per day. This limits the amount of aircraft that can be processed in a day. Approximately sixty missions per day can be generated. Increasing the number of missions per day beyond sixty has diminishing returns.

The IBCT APOE scenario is limited by the number of hazardous cargo parking spots. As the percentage of hazardous cargo is decreases, the aircraft throughput increases. Increasing the available hazardous cargo parking spots to five without decreasing the non-hazardous cargo parking increases the aircraft throughput. Currently, the IBCT will require four days to deploy because of the limitations of the hazardous cargo parking.

Recommendations for Action

From the collection and analysis of the output from the simulations, recommendations for future action were formulated for the en route and the IBCT scenarios.

For the en route scenario, it is recommended that continuous updates to the model be conducted. Using existing operation plans, USTRANSCOM can compare the requirements placed on Elmendorf AFB to what throughput it is capable of handling and necessary improvements can be identified. Additional fuel can be provided or the number of missions generated can be limited.

For the IBCT, an additional day will be required to process the required aircraft to deploy the IBCT with fifty percent hazardous cargo or the ninety-six hour deployment

constraint will need to be relaxed. Additional hazardous cargo parking will improve the throughput, but upgrading existing parking spots to hazardous capable will limit the degree of improved throughput. Consolidation of hazardous cargo onto fewer aircraft would reduce the number of aircraft requiring hazardous cargo parking, increasing throughput. Finally, the aircraft could refuel at non-hazardous parking spots and then move to on-load cargo at the hazardous spot. This would be difficult to model, but would reduce the demand on the hazardous cargo parking.

A systems approach is recommended for improving Elmendorf AFB for both scenarios. The hydrant fuel system improvements have increased the capability of Elmendorf AFB, but cargo aircraft are still parking on hardstands that are difficult to maneuver into position except for the West and North Ramps. A systems approach is recommended, so that future improvements will achieve desired effects by considering all of the potential constraints at the airfield and improvements can be made to more than one system at a time. For example, if parking were the limiting factor, improvements in throughput could only be achieved by improving the parking situation requiring the new hydrant outlets to be moved. The system approach would allow recognition of the potential constraints, so money and time could be conserved in the improvement of throughput. Parking is not the limiting factor at this time, but it may be in the future.

Recommendations for Future Research

Future research is required as the important factors for each scenario change. It is recommended that future research use a field study to allow for more accurate data collection. Some of the parameters had to be estimated based on an average because of the detail required by the AST was not known by the experts at Elmendorf AFB. The

field study allows for the measuring of travel times, loading times, delay times, etc. The estimates used were fine for this research, but the validity of the input data could be enhanced using a more qualitative approach during this stage of the research.

USTRANSCOM assumes no hazardous cargo in the en route flow. This assumption has a large affect on the throughput of aircraft, since the modeling of hazardous cargo parking closes many of the needed parking spots for an en route flow. Future research may want to include a realistic amount of hazardous cargo and determine its affect on the throughput. In conjunction with the IBCT research being conducted, the placement of the hazardous cargo parking spots needs to consider both scenarios because of the number of parking spots closed during IBCT deployment and the reality that the IBCT may be deploying in the initial days of the en route flow.

The complexity of the AST model allows for detailed simulation of all the operations necessary to process these aircraft including the staging and preparation for deployment of Army Equipment and personnel. In the two scenarios simulated, not all of the capabilities of the AST were utilized. Working with the model has led to the discovery of some irregularities in the operation and output of the model, which has led to the improvement of the model. It is recommended that the relationship between USTRANSCOM and AFIT continue to the benefit of both parties.

Conclusion

This research identified the limiting factor at Elmendorf AFB under two different scenarios using the Airfield Simulation Tool. The fuel that Elmendorf is able to receive limits the number of aircraft the can be processed through during the en route scenario. The number of hazardous cargo parking limits the timely deployment of the IBCT.

Recommended actions discuss possible improvements, the need to continue this research, and limitations of the AST model. Recommendations for future research recommend a more qualitative approach to collecting the input data. As discussed, the continuous update of this model for Elmendorf AFB and others will ensure that planners at USTRANSCOM understand the capabilities of the airfields modeled and allow for improvements to ensure that the airfields modeled are capable of meeting their wartime requirements.

Appendix A. Glossary of Acronyms

AFB	Air Force Base
AMC	Air Mobility Command
AMS	Air Mobility Squadron
APOE	Aerial Port of Embarkation
AST	Airfield Simulation Tool
BRACE	Base Resource and Capability Estimator
DLA	Defense Logistics Agency
DoD	Department of Defense
ERS	En Route System
GAO	General Accounting Office
GPH	Gallons Per Hour
GPM	Gallons Per Minute
Hrs	Hours
HSV	Hydrant Service Vehicle
IBCT	Interim Brigade Combat Team
Max	Maximum
MaxRT	Maximum Repair Time
MeanRT	Average Repair Time
MH2	Hose Cart
MidRT	Middle Repair Time
Min	Minutes

MinRT	Minimum Repair Time
MTBF	Mean Time Before Failure
USAF	United States Air Force
USTRANSCOM	United States Transportation Command

Appendix B. Raw Data

Timeframe for the data: 1 December 2000 through 30 January 2002.									
	REPAIR TIMES							Includes breaks not fixed yet	
A/C	0-4	4-8	8-12	12-16	12-24	24-48	48-72	72-MAX	Break Rate
C-5	26.9%	17.6%	12.3%	9.4%	11.7%	14.1%	1.8%	6.2%	14.7
C-17	33.7%	20.6%	11.6%	7.4%	7.2%	12.5%	0.2%	6.8%	12.0
C-130	17.3%	9.0%	6.0%	4.2%	7.4%	19.8%	0.4%	35.9%	17.0
C141	20.1%	12.4%	8.1%	6.8%	8.1%	13.9%	0.9%	29.8%	8.9
KC-10	22.4%	17.5%	12.0%	7.1%	13.7%	16.4%	5.5%	5.5%	2.2
KC-135	11.5%	8.7%	6.4%	4.1%	7.0%	6.7%	1.8%	53.8%	9.3

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Vita

First Lieutenant Andrew C. Jones was born in Green Bay, Wisconsin. He graduated from The Ohio State University. While there, he earned a Bachelor of Science in Civil Engineering. Upon commissioning, he served as a Transportation Officer at the 615th Air Mobility Operations Squadron at Travis AFB, California.

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14. ABSTRACT
Elmendorf Air Force Base (AFB) is one of the two key ERS airfields for the Pacific Theater. The condition of en route airfields has recently come to the attention of the DoD and the GAO. Delays at these airfields may cause personnel and equipment to arrive late in theater. Fuel systems at Elmendorf AFB are currently being improved, but the GAO questions whether these improvements will help the throughput. As well as being an en route airfield, Elmendorf is also an important Interim Brigade Combat Team (IBCT) APOE for Fort Richardson. The IBCT is designed to operate in small-scale contingency operations in both complex and urban locations. The IBCT will be deployed within ninety-six hours between departure of first aircraft and arrival of last aircraft. The IBCT also requires fifty percent hazardous cargo loads, which reduces available parking for safety reasons. This research uses the Airfield Simulation Tool (AST) to model both the en route and the IBCT scenarios. The focus of the modeling effort is to understand the limiting factors for both scenarios at Elmendorf AFB.

15. SUBJECT TERMS
Airfield Throughput, Elmendorf AFB, IBCT, Hazardous Cargo Parking, Airfield Simulation Tool

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